SURVEYING FOR ARCHÆOLOGISTS.

I.

WE have now two societies for the astronomical study of ancient monuments at work in Britain; a considerable number of the monuments have already been astronomically surveyed, with the result that the various alignments indicated have been shown to have been laid out to facilitate and utilise observations of the sun or stars.

It is not to be wondered at, therefore, that I have been repeatedly asked, now in one region, now in another, to put on paper some general hints to those who may feel inclined to take up the work so as to secure the necessary observations.

I think the first useful thing to say is that the inquiry is much less complex, and takes much less time in the measurement of any one monument, than is generally imagined; that the ideas involved are very simple, and do not go beyond the knowledge which should be possessed by everybody who wishes to enjoy and understand something of the world around him.

In the first place, the astronomical side of the inquiry, so far as the monuments are concerned, is very restricted. It has little to do with the various data concerning them which archæologists, with wonderful diligence, have now been accumulating for several centuries. The weight, shapes, size, colour and nature of the stones are not in question. All use of the spade for finding treasure or anything else is not in our province. If, when plans are given, the relation of the stones to each other is accurately given, we can accept them so far as the arrangement of the stones *inter se* is concerned.

One great advantage of being freed from the necessity of doing all this work is that would-be inquirers are saved the expenditure of a great deal of time and money; to them the spade is needless, because they deal only with the relation of the monument to the surrounding surface, and for the same reason the conditions of the stones themselves are indifferent to them.

What, then, is it they have to do? They have simply to determine, with an accuracy as great as can be achieved by the instruments at their disposal, the line of direction indicated by the lie of the stones in the various monuments. This problem is at its simplest in the case of the so-called "Avenues," such as those at Challacombe and Merrivale, on Dartmoor.

Do they lie east and west, or north and south, or in any other intermediate direction?

Again, take the cases of the so-called "outstanding" stones or tumuli so often met with at some distance outside the Cornish circles—those of the Merry Maidens and Tregaseal, to give instances; do they lie to the east, or the west, or the north or the south, or at some intermediate angle? and at what angle?

In the case of cromlechs or dolmens the matter is not quite so simple, except in the case of those furnished with an obvious outlook, an *allée ouverte* or *couverte*, to adopt the terms employed by French archæologists. I suppose there are hundreds of monuments of this class, of which so-called "plans" exist, but in spite of these plans, which may be quite good so far as the interrelation of the stones is concerned, we have no certain knowledge as to the exact direction in which these alley-ways or creeps point. The stones have been dealt with as stones, and their relations to their surroundings have been entirely neglected.

Fundamentally, then, to get out of this *impasse* it is a question of these directions in the first instance.

How is this to be done? It is here that the elements of knowledge of the things around us, which, I am thankful to say, now form part of the teaching in our best elementary schools, and which, therefore, are not of a very recondite nature, come in.

The ancient monuments, like everything else on the face of the earth or sea, appear to anyone who examines them close at hand to occupy the centre of a plane, which is really the little bit of the surface of the earth that we can see from any one point of view. This circular patch of land or sea is bounded in every direction by what is called the *horizon*, which is the most distant part of the land or sea from us, and on which the sky seems to rest. In the case of the sea, this horizon is level all round. In the case of the land, it may be high or low according to the surrounding conditions. If we live in a street it is high, its height depending upon the number of storeys in the opposite houses; if we are on the heights of Dartmoor it is very low, almost as low as a sea horizon, and as sensibly circular.

Suppose us, then, surrounded by this circular horizon, in front of an avenue; how, when we have measured the stones and plotted them at the proper distances apart, can we indicate the general direction of the lines of stones? We can divide the circle of the horizon, like all other circles, into 360°. But where—in what direction—are we to begin the numbering? Where must the zero be?

All mankind has now agreed for hundreds of years that the zero must be the *north* point; opposite to it is the *south* point, and the line joining these north and south points is called a *meridian line*.

This meridian line, passing along the earth's surface and joining the north and south points of the horizon, lies in a vertical plane passing through the point overhead called the *zenith*. The term meridian is used because the sun passes through this plane at the middle of each day. The line at right angles to the meridian line passes through two points on the horizon midway between north and south. These are called the east and west points, and in the four points now named we have the so-called *cardinal* points on the horizon.

The meridian so defined is called the *astronomical meridian*, and the cardinal points of the horizon involved are called astronomical or true.

The *astronomical* north and all the other points are absolutely stable; they never vary, and are always the same at all places. This north point may be roughly found at night, as it is the point of the horizon under the pole-star, the star which nearly occupies the centre of the circle round which the stars revolve in their daily apparent movement. The south point may be defined as the point of the horizon under the sun at noon.

Now all this seems plain sailing, but the trouble of it is that there are two north points and two meridians to be considered.

If we take a magnetic needle and balance it horizontally on a vertical pivot, its ends will be directed to two points on the horizon, which are not the same at all places with regard to the cardinal points. By drawing a great circle through these two points and the zenith point of the place, we obtain the plane of the *magnetic meridian*. The magnetic needle, as we see it in a pocket compass, has a marked N. end, and its length lies in and defines the magnetic meridian.

The *magnetic meridian line* is the intersection of the plane of the magnetic meridian with the plane of the horizon.

In Britain these two meridians do not coincide; at present, on the average, they form an angle with each

other of some 18°. So that the magnetic north is 18° to the west of the true north.

The angle between the astronomical and magnetic meridian lines is called the magnetic *variation*, east or west according as the north end of the needle points to the west or east of true—that is, astronomical—north at any particular place at any particular time.

Such a needle is never at rest, as it is for ever under the influence of the magnetism of the earth, which is always varying. The north point it indicates, therefore, *varies* from year to year; hence the term *variation*; it also greatly varies from place to place, so that there is nothing stable about it; another difficulty is that there may be a local magnetic attraction, caused by iron in the underlying strata, or even gas or water pipes or iron railings, which interferes with the general magnetic attraction at the place, so that a reference to a *general* chart is insufficient.

In a survey of any kind, whether of stone monuments or houses and trees on an estate, to take instances, the first desideratum is a point of reference to which all measures must be referred; but the plan as a plan is incomplete unless the relation of the point of reference used to the astronomical north, or the magnetic north, point of the horizon is quite accurately shown.

Now, the reason that so many archæologists have dealt with the magnetic meridian and the magnetic north is that it is much more easy to determine it. Unfortunately, it has not struck them that their measures of angles, *so far as direction is concerned*, are useless unless the relation of the magnetic meridian to the astronomical meridian, at the monument under investigation and at the time of measurement, has been accurately determined.

It must be confessed that there is much excuse for them, for, until a few years ago, it was difficult in the absence of magnetic surveys to obtain this relation, which consists in an accurate statement of the angle called, as we have seen, the *variation* between the magnetic and astronomical meridians, or, in other words, the angle between the magnetic and astronomical north points of the horizon.

To give a concrete case of the facts, let us consider the case of the Nile Valley, where work such as we are now considering was begun by a Commission of the French Academy of Sciences in 1798.

They found that in 1798 a magnet swung along a line extending from a little to the west of Cairo to the second cataract had a variation of 11½° to the west. In 1824, when the great Lepsius, the prince of archæological surveyors, arrived on the scene to prepare his majestic plans of the temples, he found the west variation no longer 11½°, but 8½°. At the present time the variation is nearer 4° west. But, alas! in the modern British Schools and Institutes of archæology little attention is given, to judge from the data shown in the plans they publish, to the question which we are now considering. A notable proof of this may be gathered from the fact that, in spite of all the statements and plans that have been made lately concerning the newly explored temple at Deir-el-Bahari, I have been unable to learn whether the indicated direction of the axis of the temple is magnetic or true; the only information given me, oh! shade of Lepsius! is that the variation had not been determined by the surveyors.

It will be gathered from the above that when we may have to deal with such a large change of the variation in a century, an old plan with magnetic bearings but without the date of the actual observations is worse than useless. Even when the date is given, a reference to old Admiralty charts is necessary to get even an approximation to the value of the variation. This is one objection to the use of the magnetic meridian.

But, whatever has happened in the past, for the future British archæologists can hardly be excused from neglecting to compare the magnetic meridian they may use for their plotting with the true or astronomical meridian, and stating it on their plans.

Both the Admiralty and the Ordnance Survey have lately been busily employed in determining the magnetic variation over the British Isles, and in future it will be shown on every 1-inch Ordnance map, so that every archæologist, for the expenditure of one shilling, will be able to learn the present variation at any monument he may chance to be surveying. Indeed, it may be said that some of the old difficulties are now in a large measure solved.

The Admiralty have recently prepared a map showing this variation for the British Isles for last year, from which archæologists can learn approximately the value of the variation, and hence the direction of the true north, at any place.

But because most of the difficulties connected with the observations of magnetic bearings are disappearing, it is certain that the magnetic method will still continue to be largely employed, as it is the easier to work with.

It is not too early to emphasise the important fact that for the *astronomical* study of the various directions we want, for a reason I shall state later on, more than the angle from the north point, either magnetic or astronomical, generally termed the *azimuth*. We want the angular height of the horizon where the line of direction cuts it. This is called the *altitude*.

How Azimuth and Altitude are defined and read.

Azimuths.

The Point Method.—A reference to the transactions of antiquarian societies will show that in the past the most commonly employed method of stating direction, or azimuth, has been by using a compass needle armed with a card such as is used by mariners, and hence called a mariner's compass. This, of course, gives us magnetic bearings.

In this the circle is divided into thirty-two parts, called points: four chief magnetic points, N., S., E., W.; four quadrantal points, N.E., S.E., S.W., and N.W.; and twenty-four intermediate points. If we take the N.E. quadrant, for example, the eight defining points are N., N. by E., N.N.E., N.E. by N., N.E., N.E. by E., E.N.E., E. by N. Now as these thirty-two points cover the 360° in the complete circle, each point contains 11° 15′, so that, reckoning directions in this way, there is a play of more than 10° for each statement made.

But the objection to this method of defining does not end here. If we read the bare statement that a cromlech, to take an instance, is open, say, to the N.E., one is apt to think that the true N.E. is intended; but where the variation is about 22°, as it is now in the west of Ireland, true N.E. is N.N.E. by compass, that is, two points more westerly.

This system of reckoning, then, besides being misleading, is too coarse for our purpose, so much so that even mariners are now giving it up, using degrees instead of points.

The Degree Method.—In the compass card so divided into degrees instead of points we may have 0 at both the N. and S. points (mag.), reading to 90° at the E. and W. points (mag.), or to 180° at the opposite point. Or, again, we may have 0° at the N. point (mag.), reading through the E., S., and W. points to 360°. Each mag. bearing is now defined

quite independently of any quadrant, so mag. east would read N. 90° E., and mag. west N. 270° E.

The circles of small instruments are graduated to degrees, and so the azimuths are read to degrees and estimated to half degrees. In instruments with larger circles, whether it be a circular protractor for reading azimuths on maps, or a theodolite for determining them, the degree can be read to $\frac{1}{10}$th of a degree, or even more finely, by means of a device called a vernier, on which it is useful to dwell a little, as many regard it as of a recondite and mysterious nature and avoid it accordingly, whereas it is as simple as it is useful.

The vernier is a short scale, constructed so that its divisions are smaller by a definite and convenient amount than those of the scale with which it is used. In a very simple case this difference amounts to $\frac{1}{10}$th of a scale division, and the vernier is made so that its ten divisions are equal in length to nine of the primary scale. One extremity of the vernier scale is the reference point, or zero, and if this be coincident with a scale division, the remaining divisions of the vernier will be separated from divisions of the scale as indicated below :—

Division	0	of vernier	coincident with division of scale.
,,	1	,,	falls $\frac{1}{10}$th short of division of scale.
,,	2	,,	,, $\frac{2}{10}$ths ,, ,,
,,	3	,,	,, $\frac{3}{10}$ths ,, ,,
,,	4	,,	,, $\frac{4}{10}$ths ,, ,,
,,	5	,,	,, $\frac{5}{10}$ths ,, ,,
,,	6	,,	,, $\frac{6}{10}$ths ,, ,,
,,	7	,,	,, $\frac{7}{10}$ths ,, ,,
,,	8	,,	,, $\frac{8}{10}$ths ,, ,,
,,	9	,,	,, $\frac{9}{10}$ths ,, ,,
,,	10	,,	is coincident with ,,

If then the vernier be in such a position in relation to the scale that its fourth division is coincident with

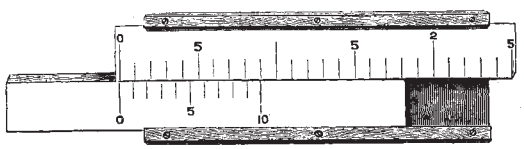

FIG. 1.—Model of a vernier showing how the divisions on a straight line can be divided into tenths. Here the vernier (below) has its zero point coincident with a division on the scale.

a scale division, the zero mark must be $\frac{4}{10}$ths removed from a scale division, and so on. In this way the coincidence of the vernier and scale divisions indicates the fractional part to be read.

It is quite easy to make a wooden model of a fixed scale and a sliding vernier; a little manipulation of this will make everything quite clear.

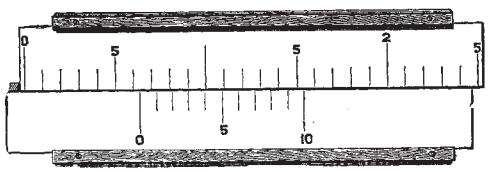

FIG. 2.—Here the zero of the vernier is between the 6th and 7th divisions of the scale. The third division of the vernier is coincident with a division of the line, so the reading is $6\frac{3}{10}$.

In a circle graduated to half degrees, the vernier is so constructed that its thirty divisions are equal in length to 29 divisions of the circle. The vernier divisions are therefore smaller than those of the circle by

$$\frac{1}{30} \times 30' = 1'$$

and the vernier is said to read to one minute. Thus to set the index of the vernier at the reading 30° 18′, first adjust it to the position 30°; then move the index towards the mark corresponding to 31°, and stop when the eighteenth division of the vernier becomes coincident with a division of the scale.

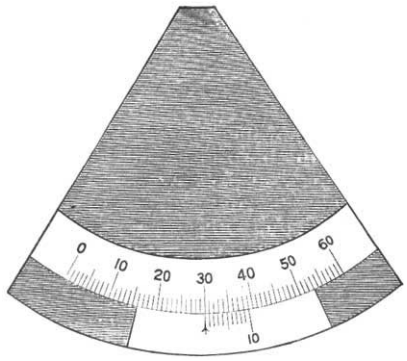

FIG. 3.—A vernier applied to a circle enabling azimuths (or any other angle) to be read to tenths of a degree.

So much, then, for the reckoning and readings of azimuth, measurements on a horizontal plane.

Altitudes.

For the reckoning of altitudes, which of course are observed with a vertical circle, the degree system is alone used, the fineness of the reading depending upon the size and graduation of the circle employed. The vertical circle is generally graduated into four quadrants of 90°, the zeros lying in the horizontal line. We can thus read elevations or depressions in degrees, or some smaller division of a degree.

NORMAN LOCKYER.

THE PERCY SLADEN TRUST EXPEDITION TO MELANESIA.

IN the autumn of last year the trustees of the Percy Sladen Memorial Fund made a grant to Dr. W. H. R. Rivers, F.R.S., of St. John's College, Cambridge, to enable him to make detailed sociological studies in the Pacific, and more particularly to study mother-right communities in the Solomon Islands, and to trace the details of the transition from mother-right to father-right. Dr. Rivers left England at the end of November, and, after staying a short time in the United States, proceeded to the Hawaiian Islands. Dr. Lewis H. Morgan, in his classical work, "Ancient Society," says (p. 403), "Among the Hawaiians and other Polynesian tribes there still exists in daily use a system of consanguinity which may be pronounced the oldest known among mankind. . . . It is the simplest, and therefore the oldest form, of the classificatory system."

The investigations of Dr. Rivers into the kinship systems of the two groups of Torres Straits islanders (Reports Camb. Exped. to Torres Straits, vols. v., vi.), and subsequent comparative studies led him to the conclusion that "as the Polynesian languages have arisen by simplification of those of the Melanesian family, so have the Polynesian kinship systems arisen by simplification of a variety resembling those found among Papuan and Melanesian peoples at the present time" (Rivers, "Anthropological Essays presented to E. B. Tylor," 1907, p. 314). In an essay (based on information obtained from natives by means of the genealogical method)